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EXPERIMENTS ON THE CONTROL OF APPLE SCAB AND BLACK ROT AND SPRAY INJURY IN 1924

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This bulletin reports the results obtained, during the past season, in the study of the control of apple scab and black-rot. Incident to the main problems there have been comparisons of spraying and dusting, and observations on many related subjects. The difficulty which led to such widespread injury from apple scab, previous to the initiation of this work in 1921, was in the spray calendar, particularly with reference to the prepink and pink sprays or dusts. Greater care in these applications seems to be absolutely essential in any thoroughgoing attempt to control this destructive disease.

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The protection afforded by lime-sulfur without the calcium caseinate spreader is so nearly complete that it is not surprising to find the use of the spreader without benefit in scab control. In fact, at both Harvard Fruit Farm and Pine Crest Orchard there was slightly less scab where no spreader was used than on plots where it was used. It is certain that the addition of the spreader to lime-sulfur-lead arsenate does not increase the efficiency of the fungicide in preventing apple scab.

A fifth application of lime-sulfur solution was applied to certain plots the middle of July because black-rot as well as scab was under observation, although neither the weather conditions nor the prevalence of scab indicated any necessity for it. This application followed six weeks of dry weather, and there was less than 2.0 per cent scabby fruit on the trees. The fifth application did not prove necessary since the protection given by four applications, as revealed at picking time, could hardly be excelled. In August, 1924, there was rain on a greater number of days than is normal for the month, and we may conclude that the necessity for a late application for scab control is affected less by the rainfall of August than by the degree of scabbiness attained by the tree in June and July.

Dry-mix sulfur-lime did not control scab as thoroughly as did lime-sulfur. In one orchard, in the plot sprayed with dry-mix sulfur-lime 8.8 per cent of the apples were scabby, and in the plot sprayed with lime-sulfur there were 0.2 per cent scabby apples. In another orchard there was 3.5 per cent scabby fruit in the dry-mix sulfur-lime plot, and 0.2 per cent scabby fruit in the lime-sulfur plot. Evidently on varieties as susceptible to scab as McIntosh, dry-mix sulfur-lime is not equal to lime-sulfur in protecting against scab.

The substitution of Bordeaux mixture for lime-sulfur for the prepink and pink applications gave practically perfect protection against scab, but the use of lime-sulfur for all applications gave protection essentially as good. Since, as is brought out elsewhere in this report, Bordeaux mixture costs somewhat more than lime-sulfur, and since Bordeaux mixture, even when used only for the prepink and pink applications, is more likely to cause fruit russeting than is lime-sulfur, the use of Bordeaux mixture at all seems to be a practice of rather doubtful value.

Results in the dusted plots.—In both McIntosh orchards the percentage of scabby apples was slightly less in the plots on which copper dust was substituted for sulfur dust for the first two applications, than in the plots dusted with sulfur at all applications. But this difference was too small to be important.

In each orchard there were four plots dusted with sulfur four, five, six and seven times respectively. The increase in the number of applications beyond four or five did not result in any consistent increase in protection against scab. The average percentage of scabby apples on plots dusted with sulfur four, five, six or seven times was as follows: Baldwins 6.9, McIntosh (Pine Crest Orchard) 3.2, McIntosh (Harvard Fruit Farm) 3.8. When the fifth application was made, about June 30, 10.0 to 15.0 per cent of the leaves were scabby. The infrequency of rains thereafter made later applications unnecessary.

Injury to Leaf and Fruit by Sprays and Dusts.

Leaf Injury.—Leaf injury was more pronounced on McIntosh than on Gravenstein or Baldwin. Leaves on check trees, which of course received no spray or dust except arsenate, were all large, flat, and uniformly green with no pale margins. Leaves on trees dusted with sulfur had practically the same appearance as leaves on check trees, that is, they were entirely uninjured and showed no tendency to curl or for the leaf margin to become pale. Leaves on trees sprayed with lime-sulphur-lead arsenate were somewhat curled, spoonshaped, or cupped. Many had pale yellowish-green margins, with some marginal burning.

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray did not reduce the injury to the leaves.

The foliage of trees sprayed with dry-mix sulfur-lime was not injured as much as that on trees sprayed with lime-sulfur. In fact, there was practically no visible injury on leaves sprayed with dry-mix sulfur-lime.

A fifth application of lime-sulfur resulted in no more leaf injury than was present on plots sprayed four times. Injury occurred when the calyx and fourth summer sprays were applied. When these applications were made, the

spray dried on the foliage in about twenty minutes and the temperature was between 55° and 67° F. These conditions are not such as are popularly regarded as conducive to spray injury. Nevertheless, spray injury as above described did occur when lime-sulfur-lead arsenate spray was applied.

Another type of spray injury, also practically confined to trees sprayed with lime-sulfur, consisted in the killing of leaf tissue under and around scab lesions.

Spray injury to the fruit as revealed at picking time.—Fruit russeting was much more severe on Gravenstein than on McIntosh or Baldwin. (See Table III.)

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray resulted, in the case of Gravenstein, in a reduction of about 50 per cent in the amount of russet. When this spray was used without spreader, 16.0 per cent of the apples were russeted; when used with spreader, 8.4 per cent of the apples were russeted. The addition of the spreader was evidently of very considerable benefit but by no means did it prevent all russeting; for there was nearly four times as much injury, even where the spreader was used, as there was on the check plot. On McIntosh plots sprayed with lime-sulfur there was so little russeting, either with or without the spreader, that no benefit from the use of the spreader was evident.

The substitution of Bordeaux mixture for lime-sulfur for the prepink and pink applications resulted in more russeted fruit than when lime-sulfur was used for all applications. In the Gravenstein orchard there was 13.1 per cent russeted fruit where Bordeaux mixture was used and 8.4 per cent on the plot on which lime-sulfur was used for all four applications. Similarly, in the two McIntosh orchards there were 14.7 and 13.5 per cent russeted apples on plots receiving the preblossom applications of Bordeaux mixture, and 0.2 and 0.4 per cent russeted apples, respectively, on plots where lime-sulfur was used for all applications.

With the substitution of copper dust for sulfur dust for the preblossom applications in the two McIntosh orchards, there were 11.1 per cent and 5.0 per cent russeted fruit. The percentages of russeted fruit in these two orchards in plots dusted with sulfur for all applications were 0.8 per cent and 0.6 per cent respectively. In the Baldwin orchard the difference was not as great: there was 2.2 per cent russet where sulfur dust was used, and 4.0 per cent russet where copper dust was substituted for the prepink and pink applications But on McIntosh, especially, there is evidence that even for preblossom applications copper dust is more likely to result in russeted fruit than is sulfur dust.

There was practically the same percentage of russeted fruits on plots sprayed four times with lime-sulfur as on plots which received a fifth application of lime-sulfur (about the middle of July).

Apparently, late applications of sulfur dust are as safe as the earlier ones, for there were no consistent or significant differences in the amount of russeting of fruit on plots dusted four, five, six or seven times.

Black-Rot and Frog-Eye Leaf-Spot.

In April and May large numbers of the pycnospores of the causal fungus were found on the surface of the bark of cankered limbs. Such limbs were sprayed in the laboratory with Bordeaux mixture or with lime-sulfur, and spores so treated would not germinate although 95 to 100 per cent of spores from limbs not sprayed germinated. This means that the preblossom applications must have disinfecting values, in that they kill such of the spores of this fungus as are at that time exposed on the surface of the bark of cankered twigs and limbs.

The first frog-eye leaf-spot was observed June 9. There was a slight increase in the number of these leaf-spots up to July 25, but there was no increase after that, at least on the marked branches used for earlier counts. On July 21, in the Baldwin orchard, 9.0 per cent of the accessible leaves on check trees, and an average of 3.0 per cent of the accessible leaves on all dusted plots had frog-eye leaf-spot.

In neither of the McIntosh orchards or in the Gravenstein orchard was there more than 0.5 per cent black-rot on fruits in check plots at picking time. Only

in the Baldwin orchard was there enough black-rot to enable us to secure any information as to relative efficiency of the several treatments in controlling this disease. In this orchard 7.2 per cent of the fruit on check trees, 2.0 per cent of the fruit on the plot dusted with copper dust followed by sulfur dust, and an average of 0.9 per cent of the fruit on all plots dusted with sulfur dust showed black-rot infection. The infection on the check was of course light, but we have some indication of the protection against black-rot given by the dust treatment.

Cost of Dusting and Spraying.

This includes the cost of materials and the cost of labor, but not the cost of equipment. The cost of treatment for one tree for the season is given in Table IV.

The labor involved was performed by two men and two horses at each orchard, except Middlesex Fruit Farm where but one horse was used. Further details as to size of trees and labor are given under the section on "Methods and Materials."

On the Gravensteins of the Middlesex Fruit Farm, 690 gallons of liquid and seven hours of labor were required to spray 100 trees. To dust 100 Baldwins here required 50 minutes and 127 pounds of sulfur dust. At Harvard Fruit Farm, 100 trees were sprayed in two hours, using 160 gallons of liquid. One hundred trees of this size were dusted in 33 minutes, using 75 pounds of sulfur dust. At Pine Crest Orchard, 100 trees were sprayed in two and three-fourths hours, using 360 gallons of liquid. One hundred trees at this orchard were dusted in 35 minutes, using 110 pounds of sulfur dust.

Although liquid lime-sulfur was not used at Harvard Fruit Farm or Pine Crest Orchard, it is also included in the record of costs for purposes of comparison.

A study of Table IV makes it evident that our cheapest method of protection is to spray with liquid lime-sulfur. Dry-mix sulfur-lime is more expensive, although the difference is not so great if dry rather than liquid lime-sulfur is considered. Bordeaux mixture is intermediate in cost between dry and liquid lime-sulfur. Use of the spreader necessarily increases the cost.

As to whether spraying or dusting is cheaper depends on the facilities for spraying, the distance from the water supply, the size of the spray tank, the size of the trees, and how many applications of dust are considered necessary. Five applications of dust were enough in 1924. This being the case, it was as cheap to protect by dusting as by spraying at Middlesex Fruit Farm. At the other two orchards, with smaller trees and less time spent in going for water, protection proved somewhat cheaper by spraying than by dusting, provided that our cheapest spray material is considered.

In most orchards where dry lime-sulfur and spreader is to be used, it is probable that the cost will not be far from that of dusting.

Summary.

The primary infection of the leaves was prevented equally well by lime-sulfur, Bordeaux mixture, and dry-mix sulfur-lime. The primary infection of the leaves was prevented more completely by spraying with lime-sulfur than by dusting with sulfur.

The prevention of pedicel infection by the fungicides improved the set of fruit.

On McIntosh plots sprayed with lime-sulfur four times, there were 1.2 per cent and 0.2 per cent scabby apples; while on their respective check plots there were 69.4 per cent and 81.0 per cent scabby apples.

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray did not result in increased protection against scab.

A fifth application of lime-sulfur did not increase the protection against scab afforded by four applications. The necessity for a late application for scab control is probably affected less by the rainfall of August than by the degree of scabbiness attained by the tree in June and July.

Dry-mix sulfur-lime did not control scab on McIntosh as completely as did lime-sulfur.

The substitution of Bordeaux mixture for lime-sulfur for the preblossom

applications gave practically perfect protection against scab, but the use of lime-sulfur for all applications gave protection which was essentially as good.

Sulfur dust gave satisfactory control of scab. In McIntosh orchards there was an average of 3.5 per cent scabby apples on plots dusted with sulfur, while on the check plots there was an average of 65.0 per cent scabby apples. No proof was secured that it is necessary to substitute copper dust for sulfur dust for the preblossom applications.

Lime-sulfur-lead arsenate spray caused foliage injury, and this was not prevented by the addition of calcium caseinate spreader. Leaves on trees dusted with sulfur or sprayed with dry-mix sulfur-lime were not visibly injured.

The addition of calcium caseinate spreader to lime-sulfur-lead arsenate spray resulted in a reduction of about 50 per cent in the amount of russeted fruits on Gravensteins.

There was a larger percentage of russeted apples on plots on which Bordeaux mixture or copper dust was used for preblossom applications than on plots sprayed with lime-sulfur or dusted with sulfur at all applications.

In the Baldwin orchard, there were three times as many leaves with frog-eye leaf-spot on check trees as on trees dusted with sulfur. In this orchard, 7.2 per cent of the fruit on check trees became infected with black-rot and the disease was present on 0.9 per cent of the fruit dusted with sulfur.

The costs of various treatments are recorded and compared. The costs of spraying and of dusting are not very far apart.

TABLE 1.—SCAB ON LEAVES

Variety*	† Treatment	Per cent Scab
Baldwins	Check	24
	Copper dust, prepink and pink; sulfur dust at calyx application	7
	Sulfur dust	11
McIntosh	Check	27
	Copper dust, prepink and pink; sulfur dust at calyx application	8
	Sulfur dust	14
McIntosh	Check	45
	Sprayed with Bordeaux, prepink and pink; calyx application of lime-sulfur	1
	Sprayed with lime-sulfur-lead arsenate, without spreader	1
	Sprayed with lime sulfur-lead arsenate with spreader	1
	Sprayed with dry-mix sulfur-lime	2
McIntosh	Check	30
	Copper dust, prepink and pink; sulfur dust at calyx application	4
	Sulfur dust	7
McIntosh	Check	34
	Sprayed with Bordeaux, prepink and pink; calyx application of lime-sulfur	1
	Sprayed with lime-sulfur-lead arsenate, without spreader	1
	Sprayed with lime sulfur-lead arsenate with spreader	1
	Sprayed with dry-mix sulfur-lime	3

* Separate orchards indicated by brackets.

† Up to June 9, through calyx application.

TABLE II.—SCAB CONTROL.

(Fruit counts in August, September and October, at picking time.)

Treatment	Number of Applications	Per cent Scabby Fruit		
		Baldwins	McIntosh	
		Middlesex Fruit Farm	Pine Crest Orchard	Harvard Fruit Farm
Check for sprayed orchards	None		69.4	81.0
Lime-sulfur without spreader	Four		1.2	0.2
Lime-sulfur with spreader	Four		2.4	
Lime-sulfur without spreader	Five		0.2	0.0
Lime-sulfur with spreader	Five			2.4
Dry-mix sulfur-lime	Four			3.5
Dry-mix sulfur-lime	Five		8.8	
Bordeaux, prepink and pink; followed by lime-sulfur	Four			0.0
Bordeaux, prepink and pink; followed by lime-sulfur	Five		0.1	
Check for dusted orchards	None	50.2	45.8	84.2
Sulfur dust	Four	9.2	1.5	5.4
Sulfur dust	Five	4.7	2.3	3.3
Sulfur dust	Six	8.5	3.1	3.8
Sulfur dust	Seven	5.3	6.0	2.8
Sulfur dust (average of plots)	Four to Seven	6.9	3.2	3.8
Copper dust, prepink and pink; followed by sulfur dust	Five	7.3	1.2	2.4

TABLE III.—SPRAY INJURY.

Russeting of Fruit.

Treatment	Number of Applications	Per cent of Fruit Russeted			
		Middlesex Fruit Farm		Pine Crest Orchard McIntosh	Harvard Fruit Farm McIntosh
		Gravenstein	Baldwin		
Check for sprayed orchards	None	2.7		0	0
Lime-sulfur-lead arsenate spray:					
Without spreader	Four	16.0		0.8	0.4
With spreader	Four	8.4		0.9	
Without spreader	Five			0.6	0.8
With spreader	Five	9.0			0.9
Dry-mix sulfur-lime-lead arsenate spray	Four				0.9
Dry-mix sulfur-lime-lead arsenate spray	Five	4.6		0.3	
Bordeaux mixture, prepink and pink; followed by lime-sulfur-lead arsenate spray:					
With spreader	Four	13.1			13.5
Without spreader	Five			14.7	
Check for dusted orchards	None		0.4	0.5	0
Sulfur dust	Four		2.3	1.6	0
Sulfur dust	Five		2.2	0.9	0.8
Sulfur dust	Six		1.3	0.5	1.0
Sulfur dust	Seven		4.8	0.3	0.6
Sulfur dust (average of plots)	Four to Seven		2.2	0.8	0.6
Copper-lime-arsenic dust, prepink and pink; followed by sulfur dust	Five		4.0	11.1	5.0

TABLE IV.—COST PER TREE.

Treatment	Number of Applications	Middlesex Fruit Farm	Pine Crest Orchard	Harvard Fruit Farm
Lime-sulfur without spreader	Four		$.33* .26†	$.19* .16†
Lime-sulfur with spreader	Four	$.56†	.35* .29†	
Lime-sulfur without spreader	Five	.60†	.39* .31†	.19†
Lime-sulfur with spreader	Five	.67†		.20†
Dry-mix sulfur-lime	Four		.38	.20
Dry-mix sulfur-lime	Five	.81		
Bordeaux mixture, prepink and pink; followed by lime-sulfur with spreader	Four	.63†		
Bordeaux mixture, prepink and pink; followed by lime-sulfur without spreader	Four		.31†	.17†
Sulfur dust	Four	.48	.30	.25
Sulfur dust	Five	.56	.35	.29
Sulfur dust	Six	.64	.39	.33
Sulfur dust	Seven	.72	.44	.37
Copper dust, prepink and pink; followed by sulfur dust	Four	.50	.36	.33
Copper dust, prepink and pink; followed by sulfur dust	Five			

* Dry lime-sulfur. † Liquid lime-sulfur.